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EXTRACTED VERSION

OPERATION HARDTACK—PROJECT 8.2

Thermal Radiation from High-Altitude Bursts

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NOTICE:
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ABSTRACT

The objective was to improve the basic understanding of the physics of high-altitude nuclear detonations by measuring the thermal radiation from the high-altitude Shots Yucca, Orange, and Teak. Spectral irradiances (H_λ) obtained by distant airborne instrumentation are presented as a function of time in four wavelength bands: 0.3μ to 0.4μ, 0.4μ to 0.5μ, 0.5μ to 1μ, and 0.3μ to 3.6μ. The measurements are extrapolated to an assumed point source, and these generalized results are discussed.

Shot Yucca, a balloonborne device detonated at 84,680 feet, radiated approximately like a black body, and, as expected, the thermal pulse had the characteristic shape of a sea level burst. Time to first maximum was approximately time to minimum was , and time to second maximum was The thermal pulse was of shorter duration than a similar low-altitude burst although the total thermal energy was about the same — 40 percent of the device yield.

Shot Orange, a device carried to 140,990 feet by a Redstone rocket, showed marked deviations from low-altitude bursts. Time to first maximum was , the minimum, which was evident only in the 0.5μ to 1μ region, occurred at about ; and the primary thermal pulse was over in . There was a shift in the spectral distribution toward the infrared. In the 0.3μ to 1μ region the total thermal energy was 20 percent of the yield whereas an extrapolated figure for the 0.3μ to 3.6μ region was 45 percent of the yield.

Shot Teak, a device carried to 250,380 feet by a Redstone rocket, had only one thermal maximum occurring at The pulse then decayed The power radiated at maximum, extrapolated to a point source, had a spectral distribution as follows: 0.3μ to 0.4μ, 0.4μ to 0.5μ, 0.5μ to 1μ and 0.3μ to 3.6μ, By subtraction, an upper bound of watts radiated at wavelengths greater than 1μ is obtained. The pronounced shift of the radiation toward the infrared is apparent.

Simple scaling laws are not sufficient to predict the thermal radiation from a high-altitude nuclear detonation. In particular the power radiated in the infrared exceeds by a large factor that expected from a black body of dimensions comparable with the visible fireball. This implies the existence of some mechanism that is producing a greater proportion of infrared radiation than would be obtained using the equilibrium black body theory.

TABLE 1.1 HIGH-ALTITUDE BURSTS AND RELATIVE AIRCRAFT POSITIONS

Shot	Yield	Altitude		P/P_0*	ρ/ρ_0†	Date, Johnston Island Time	Aircraft Position	
							Altitude	Slant Range
		km	ft					
Yucca		25.81	84,680	2.21 (−2)‡	2.91 (−2)	28 Apr 1440	11.3	24.5
Orange		42.97	140,990	2.03 (−3)	2.17 (−3)	11 Aug 2330	9.3	138
Teak		76.31	250,380	2.02 (−5)	3.20 (−5)	31 Jul 2350	9.3	137

* P_0 = 101,325 newtons/m^2.
† ρ_0 = 1.225 kg/m^3.
‡ Number in parentheses indicate the power of 10 by which each entry must be multiplied.

TABLE 1.2 PERCENTAGES OF TOTAL ENERGY RADIATED IN VARIOUS SPECTRAL REGIONS BY A PLANCKIAN RADIATOR AT DIFFERENT TEMPERATURES

Black Body Temperature	Far Ultraviolet (FUV) 0.2μ to 0.25μ	Near Ultraviolet* (NUV) 0.3μ to 0.4μ	Visible (VIS) 0.4μ to 0.5μ	Infrared (IR) 0.5μ to 1μ	Bolometer† (BOLO) λ > 1μ
°K					
1,000	—	—	—	0.035	35.
2,000	—	—	0.03	7.	69.
3,000	—	0.2	1.	27.	62.
4,000	0.03	1.8	5.	42.	47.
5,000	0.3	5.7	10.	47.	28.5
6,000	1	11.	13.	47.	24.
7,000	3	15.	16.	42.	16.5
8,000	5.	18.	16.	38.	13.
9,000	8.	21.	16.	32.	10.
10,000	10.5	21.0	15.2	27.5	8.0
11,000	11.5	20.9	13.9	23.9	6.7
12,000	13.3	20.4	13.0	20.8	5.4
13,000	14.6	19.3	11.8	17.7	4.1
14,000	15.6	18.0	10.8	15.4	3.4
15,000	16.0	17.1	9.7	13.3	3.1
20,000	15.3	11.7	5.8	7.1	1.3
25,000	12.5	7.6	3.5	4.3	0.74

* Experimentally, it was known that no radiation of wavelengths 0.25μ to 0.3μ reached the aircraft.
† The bolometer wavelength band was limited only by the transmission of quartz, ~80 percent from 0.2μ to 2.64μ and from 2.9μ to 3.6μ. The percentages presented are for energies at longer wavelengths than detectable by the dispersion units; λ > 1μ.

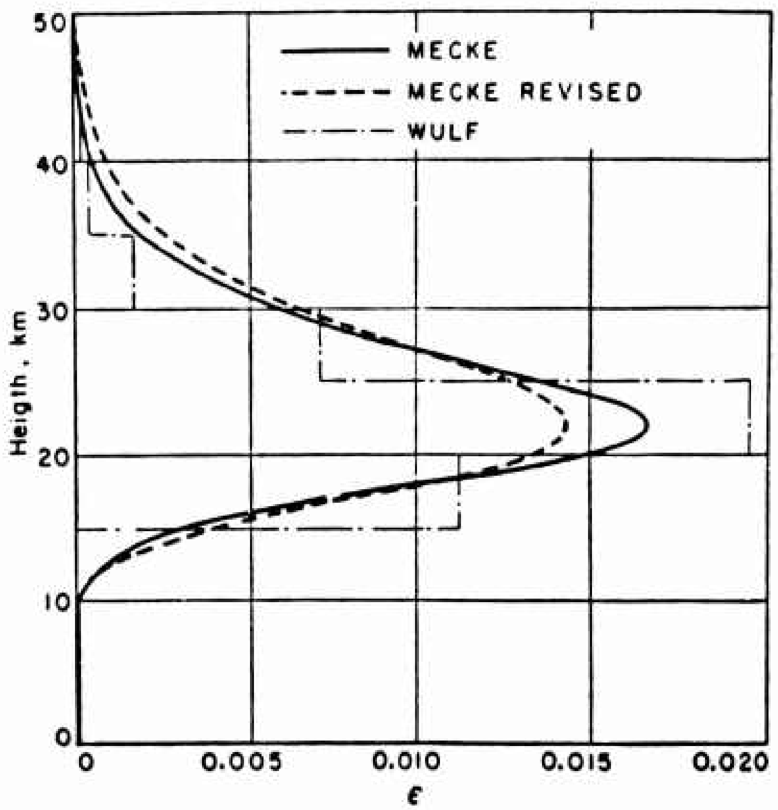

Figure A.4 Vertical ozone distribution.

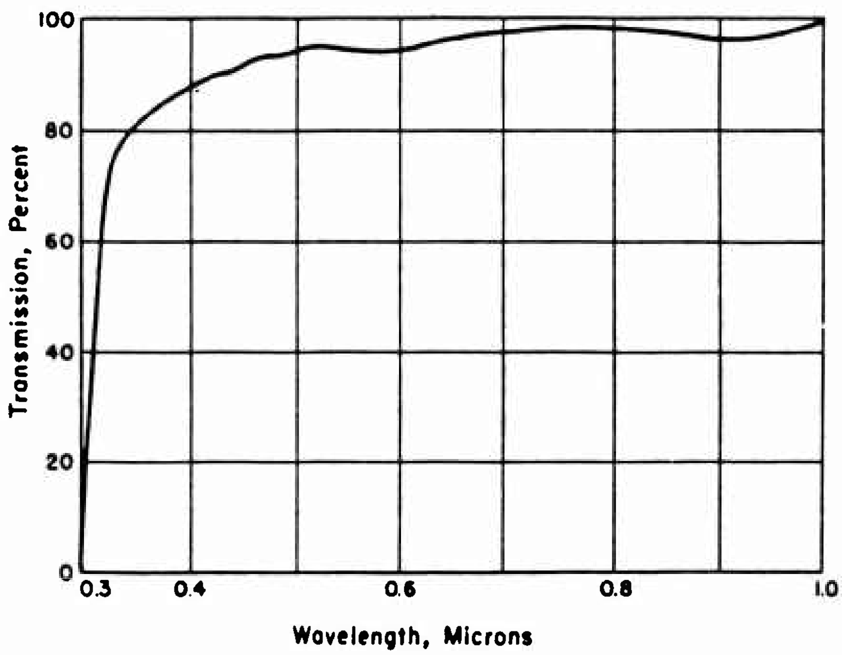

Figure A.5 Atmospheric transmission, Shot Yucca.

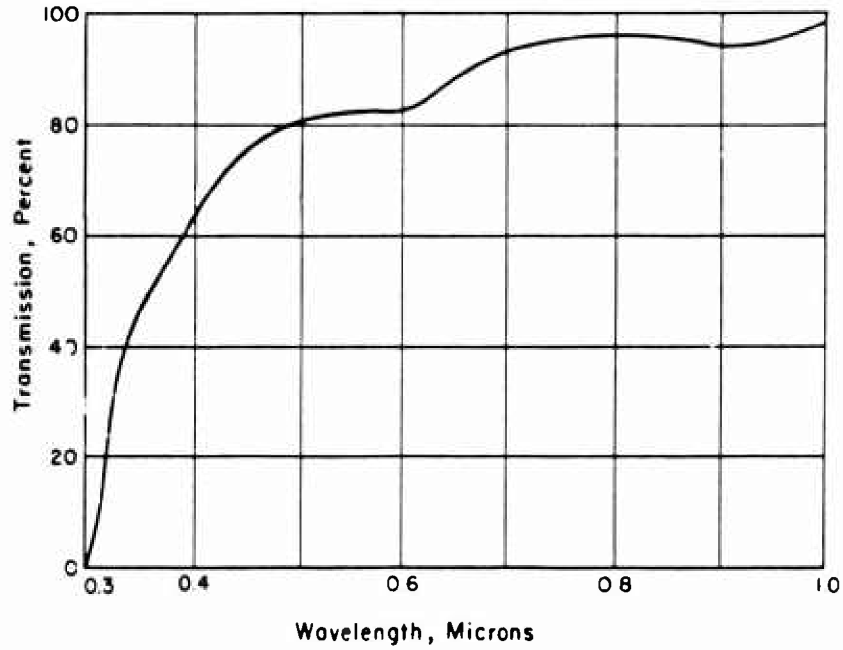

Figure A.6 Atmospheric transmission, Shot Orange.

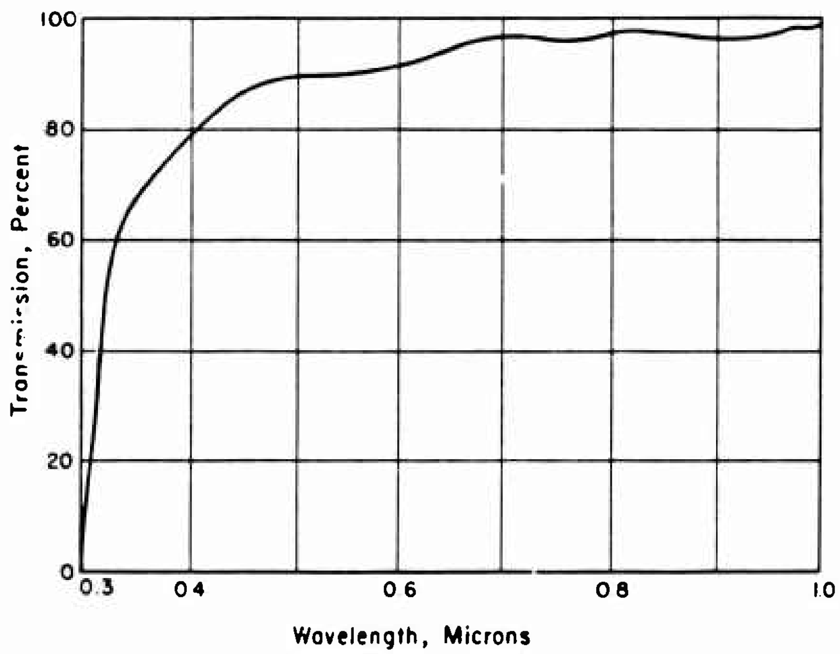

Figure A.7 Atmospheric transmission, Shot Teak.

Appendix B

BLACK BODY RADIATION AT VARIOUS TEMPERATURES

The specific intensity of radiation from an object radiating as a black body at a temperature T is given by Planck's law

$$B_\nu(T) = \frac{2\pi h\nu^3}{c^2}\,\frac{1}{(e^{h\nu/kT}-1)}$$

Integration of this function over all frequencies yields the Stefan-Boltzmann equation

$$B(T) = \sigma T^4$$

Where: σ has the value 5.6687×10^{-12} watts cm^{-2} $(°K)^{-4}$.

If, for example, the object is a sphere of radius R, then the total power radiated is

$$P = 4\pi R^2 \sigma T^4$$

and the fractional amount radiated in a frequency interval, ν_1 to ν_2 ($\nu_2 > \nu_1$) is given by

$$f_{1-2} = \left(\frac{15}{\pi^4}\right)\int_{x_1}^{x_2} \frac{x^3\,dx}{(e^x-1)}$$

Where: $x = h\nu/kT$.

By means of the tables in Reference 12, this integral can be determined with a minimum amount of computation.

In this particular case, the long wavelength transmission characteristics of the quartz window that was used in the bolometer required evaluation of this fraction in the regions from 1.0μ to 2.64μ and 2.9μ to 3.6μ. Table B.1 presents the values of xT ($x = h\nu/kT$, $xT = hc/k\lambda$) for wavelengths which pertain to the cutoffs of the dispersion units and the bolometer. For any given temperature the limits on the integral are determined, and hence, the fractional power in this interval.

TABLE B.1 WAVELENGTHS IN MICRONS TRANSFORMED TO xT $(hc/k\lambda)$

λ (μ)	xT (°K × 10^4)
0.186	7.735
0.3	4.796
0.4	3.597
0.5	2.878
1.0	1.439
2.64	0.545
2.9	0.496
3.6	0.400

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